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I. StromSight : A Deep Learning Based Cyclone Intensity Estimation Using INSAT-3D IR Imagery

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***Abstract*— Cyclone intensity estimation helps in providing a solid base for effective risk management of coastal areas. This research aims to provide a new concept of the application of deep learning technique with INSAT-3D infrared images that tends to classify the type of fire and thereby recognize the conclusion of fire fighting process as soon as possible by increasing the accuracy and speed of this task. The neural network is trained on a rich INSAT-3D IR dataset, and the ground-truth (cyclone category, pressure, wind speed and cloud patterns) data is putted into the CNN. The model tackles major problems such as represented by dynamic cyclone system and multi-parameter prediction in that, it uses MT learning for its basis to create a multi-task architecture. Relentless evaluation of accurate veracity illustrates positive trends between observed and predicted force thus showing an efficient tool of determining cyclones strength. This is a way forward that will help in achieving better preparedness and response to the increasing menace of these storms in the extending far into the ocean coastal areas that remain vulnerable.**

Keywords*— *Cyclone intensity, Cyclone Direction, Deep learning, INSAT-3D, convolutional neural network, multi-task learning, disaster management, coastal communities, INSAT-3D IR Imagery, Data

I.Introduction

The imposing force of Cyclones, which is another name of Hurricanes or Typhoons, is an example of nature's most destructive and unpredictable forces. These immense vortices, fueled by warm ocean temperatures and different meteorological conditions, can ruin large coastal parts when they move on to the land, presenting a terribly destabilizing factor for the shore. The foremost attribute that needs to be forecast very closely and precisely in no time is cyclone strength, which is vitally necessary for the formulation of effective disaster management, preparedness, and swift reactions. It is argued here that this construction has traditionally been based on a marriage of meteorological measurements, numerical weather models, and satellite photography. Meanwhile, the advent of deep learning algorithms, which outperform the classical modelling in terms of accuracy and efficiency, has indeed enabled solving this multifaceted problem. Moreover, the meteorology field has struck into a new path. This study looks into the encouraging field of deep learning to come up with a novel algorithm that could be used for predicting cyclone intensity. We especially employ the INSAT-3D, the latest version of the Indian National Satellite System, equipped with a high-grade and precise infrared thermal channel. INSAT-3D IR imaging will make our technique useful because it will come in handy for tracking, monitoring, and analysing cyclones. Therefore, it will be a perfect data source for our novel method. Rating cyclones is generally done on the Saffir-Simpson Hurricane Wind Scale or the Dvorak approach where Category 1 means a weakest cyclone and Category 5 is the strongest cyclone. Low pressure, higher wind speeds, and the cloud patterns, in general, help to characterize the storm's severity. The estimation of these factors accurately and timely is crucial, as it allows the formation of rational evacuation and resource allocation decisions, and disaster related responses. On the other hand, traditional methods often face problems in tracking fast forming cyclones, intricate clouds, and the fact that data is usually restricted. Deep learning, as a kind of machine learning and the most powerful machine learning type, has the ability to solve the complicated and data-rich task.

Convolutional neural networks (CNNs), an image analysis-oriented special class of deep learning model, present a feasible option for enhance cyclone intensity estimation. CNNs are very good at capturing relevant image features and perception automatically and this is of great value when interpreting the IR imagery of INSAT-3D. On the basis of well grounded meteorological parameters, these properties are further employed to predict cyclone intensity. The main hub of our research involves the production of a deep learning model trained on a great number of INSAT-3D IR images. These data sets, composed of cyclones of different intensities, are meticulously annotated by experts and serve as the basis for the model's training and assessment. Moreover, the model addresses the inherent intricacy of cyclone intensity estimation by using multi-task learning strategy. This technique allows the model to estimate not only central pressure but also maximum sustained wind speed, and so on, the picture becomes complete of cyclone intensity.

II.Literature Survey

In the process of our work, we conducted a thorough research on existing techniques which are being used and not only the present methods, we tried to know about techniques which are not in use too, so that we can gain a clear view at the problem and what is best way to approach it. Upon reviewing these papers, it became evident that numerous researchers have introduced a variety of authentic models for intensity estimation.. Researchers have established innovative techniques for the proper estimation of cyclone intensity , and a summary of their work is included in this section.

In their 2019 paper, Wimmers and colleagues experimented with the feasibility of using deep learning using the convolutional neural network model called DeepMicroNet to determine the intensity of TCs based on the data taken from satellite observations, among others. The focus of their works was on determining whether such innovative teaching apps can be applied in meteorology and pinpointing the room for development of these apps.The results of the model achieved satisfactory accuracy marked by a factor of 14 kt of root-mean-square error (RMSE), however, it presented certain limitations in the manner of correctly predicting the intensity of category 5 TCs because of its lack of a well-training dataset.This work conveys the strong optimism of deep learning in the meteorology discipline, especially for improving the accuracy of tropical cyclone intensity forecasts. However, there is still room for more developments in this technology.

In a study that has recently been introduced and is very innovative, Meng et al. made TCP-NGBoost model, which is advanced and managed to merge the strong and competent sides of LightGBM and NGBoost algorithms. This model is a revolutionary tool in the field of tropical cyclone (TC) intensity forecasting considering the fact that it does not only quantify the uncertainty but also it vaults the traditional TC intensity forecasting in performance. Among all, the novelty of TCP-NGBoost demonstrates its great computational efficiency, leaving behind the resource-expensive techniques of super-ensemble models, and accomplishes view that competes with the current operational models to reach accuracy in forecasting with a 24-hour interval. TCP-NGBoost is undoubtedly able to make exceptional contribution to the treatment, yet on the perky side, the report addresses TCP-NGBoost struggles, which include its complex, non-linear relationships due to limited availability of the training data and the black box nature, in which understanding its internal mechanics is much complicated. Notwithstanding, however, TCP-NGBoost is an outstanding achievement contributing to the progress of risk assessment and decision-making through a refined and probabilistic approach to forecasting the intensity of the hurricanes, thus showing a path to winning this battle against such powerful and destructive forces of nature.

The research conducted by Tian and colleagues focuses on the creation of a 3 D Convolutional Neural Network model called 3DAttentionTCNet which incorporates the Convolutional Block Attention Module (CBAM) to estimate Tropical Cyclone intensity using satellite imagery channels. By utilizing infrared (IR) water vapor (WV) and microwave (PMW) channels the model enhances the accuracy of TC intensity prediction. The study highlights the effects of combining IR and PMW channels while also noting limitations when integrating WV channels, with IR ones. Through training and testing it was found that utilizing all three channels in a 3 D CNN with CBAM leads to the precise TC intensity estimation. The incorporation of CBAM into the network enhances feature recognition and channel selection related to TC intensity resulting in improved performance with a reduced error rate of 9.48 knots. Performing a comparison of strengths and weaknesses to prior models.denote the fact that 3DAttentionTCNet surpasses other methods.In this context where satellite is primarily used for regional TC estimation shows its potential.competitive and the way in which they can dwelp improve the TC for instance.prediction. This study shows that employing journalism and mass media as tools of conflict prevention and dialogue-building can produce positive results.CNNs in 3D, with attention mechanisms for addressing the processing issue.using multichannel satellite data, in disaster situations, in monitoring and response efforts.

III.Existing System

The intensity of cyclones used to be estimated from long-term weather prediction. several conventional techniques and many of them are known to be reliable technological resources, uses asymmetric weighting of obtrusive weather systems. Such approaches, though frequently applied, usually have reduced yield. This is mainly because they are saddled by their subjective and limited approaches that depend on a certain condition like visual interpretation.

A Saffir-Simpson Hurricane Wind Scale

Saffir-Simpson Hurricane Wind Scale created during the early seventies's time was one of the common wind intensity assessments scales as according to the procedure and the most recognized one that was invented by a meteorologist Robert Simpson and engineer Saffir Herbert. Storm surge is one of the main reasons for heavy flooding caused during a hurricane disaster. The speed of wind used as a basis to categorize the hurricane. From Category 1 (74-95 mph) through Catastrophe 5 (157 mph or higher). Every category assigns some certain result, whether as an immediate danger or not, and then is used in the various emergency preparedness and public awareness plans. Nevertheless, its imperfections can be relieved by paying attention that the Saffir-Simpson scale includes. The index relates only to the wind speed which is the least significant in the series of cyclones intensity factors besides rainfall, storm surge or size which are left out of the equation. Also, the use of simple arithmetical scores is arguable due to their low level of expressiveness and, possibly, insufficient representation of all the important consequences of cyclones.

B Dvorak Technique

The Dvorak technique, developed by meteorologist Vern Dvorak in the early 1970s, found its great implementation: the latest system, created on the basis of the analysis of the images transmitted by the satellites and independent from other data, turned out to be the best visual tool for the cyclone intensity evaluation as well as dramatically popular. This one is of taking clouds' position and structure into account to decide about the nature of the hurricane at the top. Spectrum of Dvorak starts from T1.0 and goes on till T8.0, covers the numbers and wind speed. The Dvorak method, in general, is based on different indicators given from a satellite observations such as eye structure, the upper level clouds, and the different types of cirrus cloud. Despite the advantage provided by Dvorak technique in terms of data analysis and quick diagnosis, factors such as interpretation bias and dependence on an assessor expertise may influence the accuracy of results. In addition, it could have a problem with capturing the surge intensity or the differences in the development phases characterizing of the tropical cyclones. The uncertainty is with rain gauge measurements in estimating the high intensity in times of extreme conditions.

C Limitations of Traditional Methods

However, the main weaknesses are rooted in conventional techniques used to classify a cyclone category and estimate its intensity. Subjectivity and the use of human interpretation results in the creation of uncertainties that can be manifested as inconsistencies and errors in assessing the intensity. Also, these strategies will commonly bear an eye on particular characteristics related to hurricane behavior, including the speed of the wind or the shape of the cloud. However, the environmental conditions with regard to the central pressure and at last some other factors of storm intensity will be typically overlooked. Raising issues with accurate forecasts does not differ from those concerning rapidly intensifying or weakening cyclones. Because of that, the employment of prospective methods something which is clarifies the multiple data sources application and the use of advanced technologies widely facilitates the wind speed recognition and measurement error reduction.

IV.Proposed System

The whole purpose of this project is to create a technique or a method that can be used for cyclone intensity estimation as well as cyclone direction estimation with less time consumption and more accuracy as this is very sensitive and very important field in human lifes if there is any error in estimation sometimes it might lead to human life loss too, so accuracy is very important as well as time taken for estimation is also important here, if our method takes more time for estimation then the damage would already happen and even estimation of correct intensity would also be of no use, so here high accuracy and less time consumption both are very important so in order to reach the both needs we are using Deep Learning Technology more specifically we are using convolutional neural network for building our custom model. We are using convolutional neural network because we are working with image Dataset (i.e IR Images from INSAT-3D Satellite) as we know that convolutional neural network will be very useful while we are working with image dataset's and as we are building our custom model's here are building 2 different models one for Cyclone Intensity Estimation and Cyclone Directon Estimation .

Here in the proposed system, firstly we check whether there is any cyclone formation in the given image and if no then we dont perform any task but if there is any cyclone formation then we send that image to both Intensity and Direction Estimation models after that both models will give their outputs that is intensity estimation model will give Intensity value in Knots(i.e scale for measuring cyclone intensity like kilometers per hour in measuring speed of vehicle's) and direction estimation model will give the direction in which the model is moving .

A. Data extraction and data cleaning

Data extraction and cleaning play a critical role in cyclone intensity and direction estimation, as it directly impacts the accuracy of the model. The first step in the data extraction process is to obtain high-quality images of INSAT 3D Satellite. The data cleaning step is as follows. The images will be displayed in the following section. In this methodology, all garbage and weak data are removed from the dataset so that the model can learn only from clean data patterns. This could be accomplished by removing images with poor quality, unreliable labeling, and images that are repeated multiple times. A non-biased model can be created by ensuring that there are a sufficient number of pictures of both positive and negative activities. This step was unnecessary because the data had already been preprocessed in the project. Only if we intend to create our own dataset will we need to do some preliminary preprocessing.

Likewise, the second step is for us to perform pre-processing and then extracting the features. It includes image rescaling for a display of consistent dimensions, and a correction of image pixel values that are converted to the needed model type later. Along with the data augmentations like rotation, flipping or zooming, there is an additional method that is adding an image to the existing set. In addition, pre-processing steps are being done for the each image before they are added to database in generalization of model to new data.

In conclusion, data extraction and cleaning are crucial steps in the cyclone intensity estimation and cyclone direction detection process, as they directly impact the performance of the model. By obtaining high-quality images and carefully cleaning the dataset, we can ensure that the model learns only from relevant patterns and generalizes well to new data.

B. REGRESSION Using Convolutional Neural Networks

C.

Layer (type)	Output Shape	Parameters
input_1 (Input Layer)	(None, 256, 256, 3)	0
conv2d (Conv2D)	(None, 256, 256, 256)	7168
Batch Normalization (Batch Normalization)	(None, 256, 256, 256)	1024
tf.nn.relu(TFOpLambda)	(None, 256, 256, 256)	0
conv2d_1 (Conv2D)	(None, 256, 256, 256)	590080
batch_normalization_1 (Batch Normalization)	(None, 256, 256, 256)	1024
tf.nn.relu_1 (TFOpLambda)	(None, 256, 256, 256)	0
max_pooling2d (MaxPooling2D)	(None, 128, 128, 256)	0
Flatten layer	(None,4096)	0
Output Layer(Dense Layer)	(None,1)	0

Total parameters : 1778961 Trainable parameters : 1776497 Non-trainable parameters: 2464

Table 2: Table of CNN Layers Output Shape and Number of Parameters

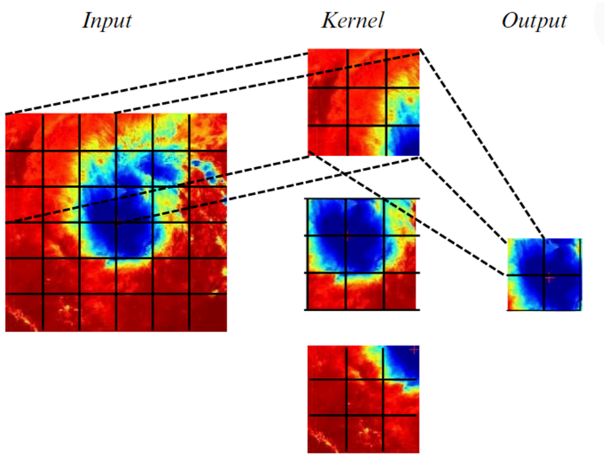

Figure 1: Convolutional Layer

a. Convolutional Layer

Convolutional layers are pivotal elements in the Deep Learning.Initially the image was divided into a 2x2 matrix holding their RGB, length, and width in each cell.The Conv2D are the 2 dimensional convolutional layers which performs mapping of the input image.The kernel plays a key role in filtration of the image through iterations of the every cell emerged in the matrix.These Conv2D layers will filter the input IR image of the cyclone and computes the dot product of the image positions to extract the patterns.These patterns are helpful to classify the IR images of the cyclones for feature mapping.The input IR image is normalized to increase the data gain by rescaling and recentering of the image data called Batch Normalization.

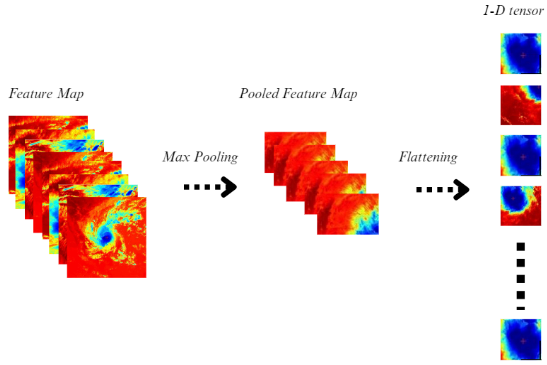

Figure 2: pooling layer and Flatten Layers

b.Pooling Layer

Pooling is the process of data reduction where the blocks of the image with maximum or average features are merged into a single block through certain operations.These blocks will enrich the features by collecting the cyclone eyewall patterns of the IR image where the detection and processing time will be reduced.The flatten layers will convert the multi dimensional tensor generated from the pooling layers to a one-dimensional tensor.

c.Activation function

Rectified Linear Unit (ReLU) is the prominent activation function situated at the dense layers of the Neural network which will results the maximum for the positive and zero for all the negative. ReLU is the most effective activation function connected to the output of the flatten layers and results the output to the fully connected layers.ReLU exhibits the Non-linearity property and resolves the vanishing gradient issue compared to other variants.

d.Fully connected layers

Every neuron carries out a linear transformation on the input vector using a weights matrix. This setup guarantees the establishment of all potential connections between layers, signifying that each element in the input vector directly impacts every element in the output vector.

D. USER INTERFACE

Simplicity and accessibility are priorities in the design of StromSight’s user interface. Due to it's user-friendly nature people with little to no experience in computer science can use it. The interface enables users to quickly test the application and all of its features without needing in-depth technical knowledge.
Images of cyclone that the user wants to be estimate it’s intensity and direction of cyclone can be uploaded to the system through StromSight's Interface. Next, using the Convolutional Neural Network (CNN) architecture—the interface swiftly analyzes the submitted photos. This CNN variant has been taught to accurately estimate the intensity and direction of cyclone.

After the analysis is finished, the user is provided with intensity value of IR image of cyclone uploaded in Knots along with direction ie either north direction or south direction or east direction or west direction.

V.Working

The project includes two key components for cyclone analysis: a direction prediction model and an intensity estimation model. These models use convolutional neural networks (CNNs), a deep learning technology, to process INSAT-3D IR images and generate insightful results.

Thermal vision analysis by the intensity estimation algorithm is the highlight of the technique. It consequently follows the CNN (Convolutional Neural) network architecture which was earlier trained using the dataset that constituted photographs taken during cyclones. In parallel with the release of AI products, the probability to become a potential tool to obtain the expected or unexpected goals rises identifying the similarities and dissimilarities of clouds, we can then arrive at the different formations the destructive force of tropical cyclones is proportional to the water temperature which is the dominant factor of their strength. These tool has got the methods which are optimized, say an example through the ADAM optimizer with the MSE loss function should facilitate in placing the errors in the results and make the result more accurate in which case regularization should be used to avoid overfitting and to keep training model accuracy uniqueness of the tent to be storm-proof in different cyclone-related circumstances.

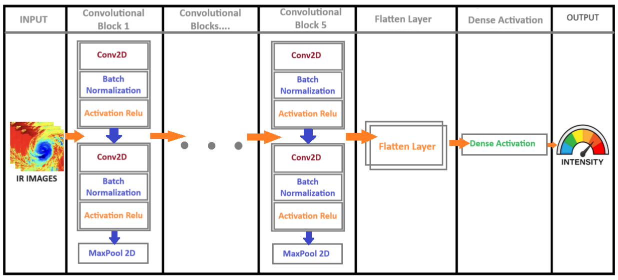

Figure 3:Flow of Images through Multiple Layers

CNN is just like that one, which is a model for distance prediction. We are considering the use of the software and algorithms for detecting the thermals with a purpose of forecasting cyclones that are barrel shaped and move horizontally.It does the winding, for instance, the ability to identify the images and the things they have in common as well as the repetitive pattern. In addition, there are different kinds of impulses - roundabouts, for instance, formations. On the other hand, they have a tendency to be more accurate because they receive techniques like categorical. L - cross-entropy by using the Adam algorithm for the purposes of the optimization a predictor that will form the four possible directions of the cyclones by giving out the direction to the north, south, east and west the model gets skillful as the forecasts are made, leading to the model being better thanks to this.

These calculators could be embedded into the app for the Streamlit Application as user friendly tools for comparison of electricity prices. This smooth link allows users to upload infrared photos of cyclones and obtain instantaneous, real-time forecasts about the movement's direction and strength. Because of the accuracy, dependability, and user-friendliness of the interface, users are equipped with the knowledge and resources they need to effectively prepare for and minimize future disasters.Comprehensive evaluations are carried out with independent test datasets in order to validate the models' performance. This guarantees the models' ability to forecast cyclone parameters with accuracy and shows their promise for cyclone analysis jobs in the actual world.

VI.Results & discussion

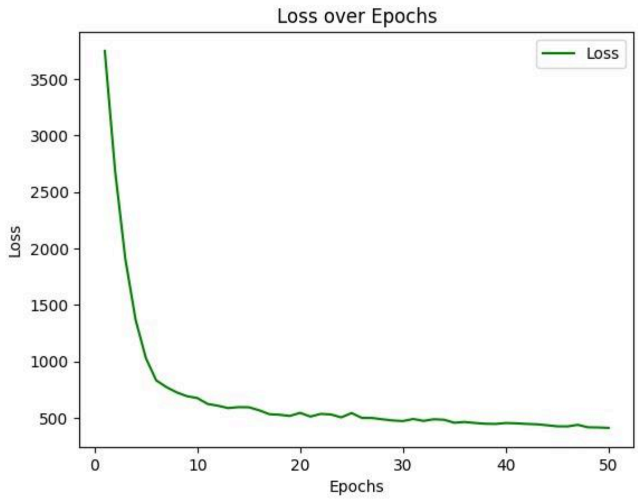

Figure 4: Graph of Loss over Epochs

The above graph describes the losses occurred for every epoch performed by the model.Initially the loss of the model is very high because it was not totally trained with the images.The MSE of the model for the first epoch is 3623.62. We have performed 50 epochs to train the model with various IR images of the cyclones with different intensities. The model has trained itself with every epoch and reduces the loss percentage and increases the accuracy . As per the graph we can notice that there was a vast difference in the detection of the cyclone intensity for first 10 epochs.

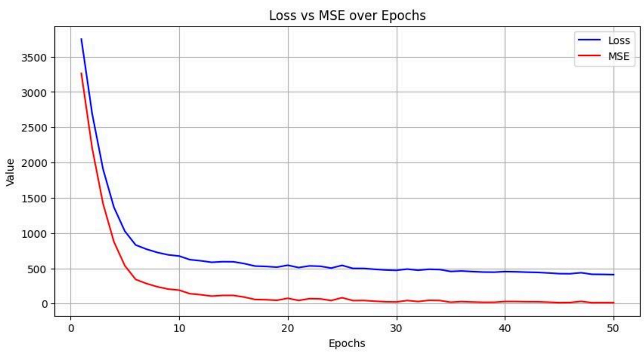

Figure 5: Graph of Loss VS MSE

The above graph describes the losses occurred in comparison to Mean Square Error over total 50 Epochs on which the model is trained initially the MSE value at first epoch was 3263.6118 and the loss value is 3749.2905 gradually it came down i.e loss is loss: 410.2502 and MSE is 12.4838 which is very huge change and increase in the accuracy of the model

VII.Conclusion

The Cyclone Intensity Estimation module achieved impressive performance with a RSME of 3.53 and an accuracy score of 87%. This signifies that the model's predictions closely matched the actual labels, indicating robust learning and prediction capabilities. The low RSME value suggests that the model effectively minimized errors during the training process , we have reduced the loss value to 410.2502 and by performing good training we were able to reduce the Mean Square Error of the model to 12.4838

VIII. Future scope

While working on getting intensity and direction of cyclones, we should also significantly improve our system capable of predicting what losses could be expected as a result. It implies the determination of valuable parameters, such as where exactly the cyclone will come closer to the landand hit. We also have to take into account the number of people who live in those areas, so we are able to understand the human effects. Furthermore, we need to include sectors within, such as factories and industries since they could be damaged too. Also, there is a need to evaluate each farmland to know farmers' livelihoods could be affected. The comprehensive approach we are taking would be to paint a vivid picture of a cyclone's destructive power, this way we can think of proactive steps to take in order to get prepared and to be able to respond adequately. Upon conditioning the storm surge and wind speeds into our estimation process, we will be able to utilize our resources better and plan evacuations earlier, thus saving the coastal population from the cyclone's impact.

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